An Intelligent Metaheuristic Framework for Multi-Robot Coordination in Evolving Environments

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

by

Tushar Gupta
Registration No. MRUMEDN012K250023

Under the supervision of

Dr. Priyanka Bansal
Program Head & Professor, R & AI

Dr. J P Sharma
Associate Professor, R & AI

Department of Mechanical Engineering
School of Engineering

MANAV RACHNA UNIVERSITY

Year *2026*

MANAV RACHNA UNIVERSITY

Date:08-03-2026

DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis entitled ***An Intelligent Metaheuristic Framework for Multi-Robot Coordination in Evolving Environments*** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of **Mechanical Engineering** under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2025-26.

It is the work that is expected to be carried out under the supervision of **Dr. Priyanka Bansal** and co-supervision of **Dr. J P Sharma**.

Further, it is declared that the short synopsis is within the plagiarism limit and a copy of the same is attached as per the University norms.

Tushar Gupta
Registration Number: MRUMEDN012K250023

MANAV RACHNA UNIVERSITY

Declared as State Private University vide Haryana Act 26 of 2014

MANAV RACHNA UNIVERSITY

Date: 08-03-2026

CERTIFICATE BY SUPERVISOR(S)

This is to certify that, the short synopsis entitled ***An intelligent metaheuristic framework for multi-robot coordination in evolving environments*** is an original piece of work done by research scholar **Tushar Gupta** under the supervision of **Dr. Priyanka Bansal** and co-supervision of **Dr. J P Sharma** for the degree of Doctor of Philosophy in the **Department of Mechanical Engineering** under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2025 – 2026.

Further, it is certified that the short synopsis is within the plagiarism limit and a copy of the same is attached as per the University norms.

Signature of the Supervisor
Dr. Priyanka Bansal
Professor, R & AI

Signature of the Co-Supervisor
Dr. J P Sharma
Associate Professor, R & AI

ABSTRACT

The autonomous multi-robot systems have been adopted as one of the central research topics in the field of robotics in the sense that it is able to perform intricate tasks successfully through the assistance of the cooperative behavior. Most of activities in which robots are currently utilized in the present time include disaster management, environmental inspection, search and rescue, warehouse automation and space research. These are currently being operated using groups of robots that can explore and work in large scale and unpredictable conditions. Multi-robot systems have several advantages compared to single-robots that comprise the ability to do jobs at the same time, high coverage efficiency, and have more fault tolerance and can accomplish missions more quickly. Nevertheless, the problem of efficient coordination of the various robots is still a challenge to be solved which includes allocation of the tasks, lack of communication, collision avoidance, exploration continuity, and environmental dynamics etc. Conventional multi-robot coordination relies on deterministic algorithms, which are effective in structured domains but struggle with dynamic and unstructured environments. With growing robots, the scalability and computational complexities also come into play which is more daunting with uncertain sensor data due to real-world examples. But adversity also nurtures agility. The goal of this research is to provide a scalable and adaptive coordination framework for multi-robot systems to improve autonomy, robustness, and efficiency.

Keywords - multi-robot coordination, metaheuristic optimization, autonomous

CONTENTS

S. No.	Description	Page No.
	Cover Page	i
	Declaration by Scholar	ii
	Certificate by Supervisor(s)	iii
	Abstract	iv
	Table of Contents	v
1.	Introduction	1
2.	Literature Review	2
3.	Identified gap in literature	4
4.	Rationale/ Significance of the Study	6
5.	Problem Statement	6
6.	Objectives of Research	7
7.	Methodology	8
8.	Comparative Analysis	9
9.	Expected outcome of the Research	11
10.	References (Harvard Style/APA/MLA)	13
	Similarity Verification Report	15

1. Introduction

Autonomous mobile robots have a wide range of real-world applications in warehouse automation, environmental monitoring, disaster response or recovery, surveillance and planetary exploration. These tasks frequently include cleaning and exploration in complex, unknown environments and entail search, mapping, area coverage, and exploration by the robot [1], [2]. Yet, traditional single-robot systems fall short of efficiency, scalability and robustness in larger or dynamic environments. So, these limitations prompted for multi-robot systems providing a more efficient and dependable method for performing complicated tasks in harsh environments.

With the advancement in field of robotics, multi robot system are making its space to provide parallel task completion, high fault tolerance, and less time to accomplish the mission. However, several other issues start raising upon including multi robots, which include responsibility distribution, communication boundary, map merging, collision avoidance and eliminating redundant paths [3], [4]. The foremost requirement for a multi robot system is to have coordination between robots which are scattered here and there into the environment thus reducing the overlaps and maximizing the coverage efficiency.

If the coverages can be coordinated well, you can reduce redundancy and maximize coverage. Robots use techniques of mapping and localization (e.g., frontier exploration, SLAM) [2], [5], but they are challenged by computational complexity or communication overhead. Dynamic environments further increase difficulty. Promising solutions exist through metaheuristic algorithms such as PSO, GA, and ACO which creates a demand for ability of solving complex optimization problems in robotics as path planning, allocation of tasks and coordination[6].

Hence, there is a high demand to create an intelligent metaheuristic scheme that would be capable of coordinating the activity of multiple robots in a dynamic world.

2. Literature Review

Most of these studies focus on coverage planning methods like wavefront, spanning tree and cellular coverage [10]. This gives rise to challenges such as task allocation, communication limits, map merging, collision avoidance and redundancy. Coordination is crucial to avoid duplication of efforts and to ensure comprehensive coverage. It trains robots to use techniques for mapping and localization, such as frontier exploration and SLAM, all of which suffer from drawbacks like computational complexity and evolving environments.

Thematic Category	**Authors & Year**	**Core Focus / Methodology**	**Key Contributions & Relevance**
Foundational Exploration & Mapping	Yamauchi (1997)	Frontier-based exploration [2]	Introduced the classic "frontier" approach (boundaries between known/unknown space) for autonomous exploration.
	Simmons et al. (2000)	Coordination & Mapping [4]	Early demonstration of coordinating multiple robots for efficient area exploration and map building.
	Choset (2001)	Coverage Robotics Survey [1]	Comprehensive baseline survey on single and multi-robot coverage algorithms.
	Koenig et al. (2001)	Ant Coverage Algorithms	Demonstrated efficient coverage using bio-inspired, pheromone-like "ant" algorithms.
	Buonocore et al. (2016)	FastSLAM Implementation [5]	Practical implementation of FastSLAM filtering for accurate indoor mapping and localization.
Coordination, Partitioning & Task Allocation	Zlot et al. (2002)	Market-Based Exploration	Pioneered auction/market-based architectures where robots bid on tasks to optimize multi-robot exploration.
	Burgard et al. (2005)	Cost-Utility Coordination [3]	Developed probabilistic approaches to coordinate robots by balancing the utility of target areas against travel costs.
	Hazon & Kaminka (2005)	Redundancy & Efficiency [10]	Analyzed the trade-offs between spanning tree redundancy, coverage efficiency, and system robustness.
	Pavone et al.	Distributed	Proposed distributed algorithms for

	(2011)	Partitioning [11]	mobile sensor networks to partition environments efficiently.
	Jain et al. (2012)	Circle Partitioning Method [12]	Introduced techniques for robot dispersion and area exploration using geometric circle partitioning.
	Emam et al. (2020)	Heterogeneous Task Allocation [16]	Addressed task allocation in teams where robot capabilities are unknown or evolve over time.
	Samson & Agmon (2020)	Competitive Coverage [9]	Explored coverage through a game-theoretic lens, showing how full information changes competitive dynamics.
Communication Constraints & Connectivity	De Hoog et al. (2010)	Comm-Limited Exploration [7]	Addressed the challenge of maintaining exploration efficiency when communication ranges are restricted.
	Banfi et al. (2018)	Recurrent Connectivity [13]	Proposed strategies requiring robots to periodically reconnect to share data, balancing exploration with network limits.
	Quattrini Li et al. (2020)	Communication Maps [19]	Developed online sensing strategies allowing robots to build spatial maps of signal strength/communication quality.
	Saboia Da Silva et al.	ACHORD Architecture [20]	Introduced communication-aware coordination designed specifically for environments with intermittent connectivity.
	Cappel (2021)	Hierarchical Mapping [6]	Designed a mapping architecture tailored to function reliably despite strict communication constraints.
	Chaabi (2025)	QoS Constraints [15]	Recent work on distributed exploration enforcing Quality of Service (QoS) constraints and connectivity maintenance.
Taxonomies, Resilience & Reviews	Prorok et al. (2021)	Resilient MRS Taxonomy [21]	Moved beyond simple "robustness" to define a complete taxonomy for resilient multi-robot system design.
	Verma &	MRS Challenges	Provided a modern breakdown of

	Ranga (2021)	& Scope [14]	multi-robot coordination taxonomy, current challenges, and future scope.
	Gielis et al. (2022)	Communications Review [17]	Delivered a critical analysis of how communication architectures impact multi-robot system performance.
	Licea et al. (2024)	Wireless & Robotics Tutorial [18]	Bridged the gap between wireless networking and robotics, highlighting the intersection of both fields.

3. Identified Gaps in Existing Literature

A comprehensive survey of the literature suggests that though significant advances have been achieved in autonomous exploration and coverage path planning, there are a number of acute bottlenecks that do not allow the successful implementation of the multi-robot systems in highly unpredictable, real-world environments. Although the new methods of SLAM and partitioning are highly developed, the significant gaps in research still have not been properly addressed:

Gap 1: Inefficacy of Deterministic Algorithms in Highly Dynamic and Changing Environments

After the relative reliance on deterministic algorithms and mathematical frameworks, certain gaps have been identified. A major shortcoming in the existing literature is the extreme dependence on deterministic algorithms and fixed mathematical models. Classical coverage algorithms (e.g., cellular decomposition, spanning tree) and the general work of frontier-based exploration are specifically crafted to operate in a static environment or in an environment whose characteristics are thoroughly known. In dynamically changing situations, when obstacles are dynamic, topographies are dynamic, sensor noise is high, or any combination of these, these deterministic algorithms are susceptible to recalculation delays and therefore provide sub-optimal solutions, freezing behaviors, or mission failure. Adaptive frameworks that will be able to automatically respond to continuous changes in the environment without fail, computationally intensive recalculations to the map are clearly lacking.

Gap 2: Exposure to Discontinuous Communication and Bottlenecks Areas of weakness

Most of the literature on coordinating multi-robots implicitly assumes that the communication networks are stable and at high bandwidth. But in practical use as in disaster response or

planetary exploration, communication is often degraded, limited or simply intermittent. The centralized and hierarchical coordination structures produce single points of failure and experience severe latency in case the network becomes unstable. There is a major loophole in the literature in creating complete decentralized, robust coordination schemes capable of smoothly sustaining swarm cohesion, task distribution and map merging in a stringent Quality of Service (QoS) and connectivity environment.

Gap 3: Scalability Problems of Multi-Robot Task allocation As the swarm size grows, the computational complexity of the problem of coordinating the actions of the robots tends to increase exponentially. Although the environment partitioning methods (e.g., Voronoi or clustering-based methods) aim at the workload distribution[11], [12], they cause enormous computational overhead in case of continuous updates to the workload because of the changing environment. The existing literature does not provide lightweight, scalable models of coordination that can enable swarms to scale to large sizes without imposing an overwhelming load on the processing capacities of onboard units of those robots.

Gap 4: Inadequate Applications of Adaptive and Hybrid Metaheuristics to Real-Time Optimization

Although metaheuristic optimization methods (e.g., GA, PSO, ACO) have recently enjoyed traction in optimization of complex robotic planning problems, they are typically used in an offline or in a static setting. Regular metaheuristics may be affected by premature convergence or long processing time, and as such are hard to apply to real-time split-second decision-making in changing terrain. A gap in the literature does exist in terms of hybridized and intelligent metaheuristic algorithms capable of varying their own algorithmic parameters (e.g. mutation rates in GA, or inertia weights in PSO) dynamically in real-time based on environmental feedback.

Gap 5: Multi-Objective Optimization Requirements are in Conflict

Multi-robot exploration is not often a single-objective problem. It involves a fine, concomitant coordination between maximizing the coverage of the areas, minimizing unnecessary exploration (redundancy), minimizing the overall energy expenditure, and preserving links with

communication. Most of the current literature works address only one or two of these variables at a time. The desperate requirement is the need to have an integrated framework that can achieve multi-objective optimization in the true meaning of the term, where the conflicting objectives can be weighted dynamically with the current state of the environment and the remaining resources of the swarm.

4. Rationale / Significance of the Study

The growing use of multi-robot systems in disaster management, environmental monitoring, industrial automation, and space exploration underscores the importance of highly efficient and robust coordination mechanisms. When operating in autonomous mode, a multi-robot system's mission may be successful or completely unsuccessful. Deterministic or centralized algorithms are used in the multirobot exploration systems that are currently in use. However, these algorithms work well in environments that are fixed or controlled, but they abruptly fail in dynamic environments where obstacles cannot be anticipated in advance. Therefore, when deploying a multi-robot system, communication overhead, unclear sensor data, and shifting environmental conditions make it more difficult for the robots to communicate with one another and raise the likelihood of failure. As more and more robots are added, it becomes simpler to look for a single point of failure or communication bottleneck because the entire system is controlled centrally. The intricate multi-objective optimization problems that are present in state-of-the-art robotics will have highly adaptable and dedicated solutions thanks to metaheuristic optimization techniques.

The proposed study will bridge this gap with a solid intelligent metaheuristic framework that could be transferred to dynamically arrange the various robots operating under the fluctuating environments between the conventional robotic control with classical control and the emergent benefit of the evolutionary computing. This will make the system more robust with a drastically improved performance.

5. Problem Statement

Although multi-robot coordination and exploration system has made remarkable progress during last few years but some serious challenges have not been addressed so far. These issues make multi robot system impractical to use practically. Some of such bottlenecks are discussed

as follows:

- **Unpredictable and dynamically changing environments:** Conventional algorithms are prone to failure for dynamically changing terrain or environment. Effective coordination is required between multi robot system in such dynamic environment where obstacles and terrains can change their position at a fast rate.
- **Redundancy leading to resource wastage:** The existing frontier-based and SLAM-based exploration algorithms behaves in an awkward manner if numerous robots examine the nearby space simultaneously. The biggest problems that need attention is time wastage and quick depletion of the battery in seriously not so required exploration
- **Degradation of Communication:** Existing models are based on high-speed communication and having enormous bandwidth. To curb the drawback of communication and make sure that the distributed decision making is effective in the case when there are sporadic or poor signals is one of the most significant problems that cannot be solved.
- **Scalability limitations of algorithms:** Deterministic and centralized algorithms can be described as having exponential scalability in their computational overhead to swarm size. The scalability of coordination algorithms to larger numbers of robots is of great importance to large scale deployments[14], [21].
- **Absence of Real-Time Flexibility:** The integration of the adaptive optimization techniques that can make decisions within time in the case of uncertainty is very sharp [8].

Hence, there is a desperate necessity to create an intelligent metaheuristic-driven coordination system that can be implemented to dynamically optimize the work of the robots, distributing the tasks and the exploration plans in such a way that they are efficient and resilient to the changing environment.

6. Objectives of the Research

The main objectives of the proposed study are:

- To analyze and find out drawbacks in existing multi-robot coordination and exploration algorithms in dynamic environment.

- To develop a smart metaheuristic system of robot coordination.
- To devise optimization models of task allocation, path planning and environment exploration.
- To test the suggested framework with the help of simulation and performance analysis with regard to efficiency, scalability, and robustness.

7. Methodology

A multi-phase open, structured methodology will be adopted to meet the objectives of the research, where the theoretical modelling is replaced by rigorous validation of simulations.

Phase 1: Systematic Literature Survey and Gap Analysis - A systematic literature review of the available literature on multi-robot coordination, coverage path planning, exploration on the basis of SLAM, and the use of metaheuristic optimization methods will be carried out. This step will be used to benchmark the existing state-of-the-art algorithms and accurately measure their shortcomings in terms of scalability and dynamically adaptable characteristics.

Phase 2: Advanced Problem modelling - Multi-robot coordination problem will be mathematically modelled as a multi-objective optimization problem. The modelling will specifically take into consideration:

- Dynamic conditions of the environment: The inclusion of moving obstacles and evolving topographies.
- Communication limitations: Signal degradation and latency as well as intermittent connectivity zones modelling.
- Task allocation and path planning: The allocation of cost functions of travel distance and task priorities.
- Energy use and exploration efficiency: Trading between high area coverage and battery life limitations.

Phase 3: Intelligent Metaheuristic Framework development - The main outcome of this study will be to design a new optimization framework. Algorithms that we are going to develop will include:

- Particle Swarm Optimization (PSO): Modified to various continuous path optimization

and distributed space coordination.

- Genetic Algorithm (GA): It is used in discrete tasks assignment and optimization of heterogeneous robot tasks.
- Hybrid Metaheuristic Methods: Hybridization of the global elimination of GA and the intensive localization of PSO to moderate exploring and exploitation in real-time. These algorithms will form the intelligence behind to dynamically optimize the robot coordination, path planning and exploration strategies.

Phase 4: Simulation and Integration - To provide safe and intensive testing, the proposed framework will be applied and widely tested in high fidelity simulation environments:

- MATLAB: To protype the initial algorithms, mathematically validate and numerically analyze the metaheuristic models.
- ROS (Robot Operating System): To create the middleware nodes to enable distributed control architectures and communication.
- Gazebo Simulation Platform: To simulate realistic physics, sensor noise (LiDAR, odometry), dynamic obstacles and real-world kinematic constraints.

Phase 5: Performance Analysis and Comparative Evaluation - The framework will be subject to the intense benchmarking against the classical algorithms on the baseline (e.g. frontier-based exploration, deterministic Voronoi partitioning)[11]. The effectiveness of the suggested solution will be measured with the help of such key quantitative measurements:

- Total exploratory time: Total time needed to survey a known percentage of a previously unknown space.
- Area coverage efficiency: This is the ratio of newly covered area and time with the objective of minimizing redundant courses.
- Energy consumption: The total kinetic energy that is used by the swarm.
- Communication overhead: The bandwidth needed to keep swarms together.
- Collision avoidance performance: Near-misses or necessary emergency stops.

8. Comparative Analysis

A comparative analysis will be thoroughly performed to strictly prove the effectiveness and strength of the suggested intelligent metaheuristic architecture. The suggested framework will be compared to the currently available, state-of-the-art algorithms of multi-robot coordination

and exploration. This comparative research is aimed at measuring efficiency and scalability and adaptability improvements in changing environmental conditions. The analysis is going to be split into the following structured phases:

8.1 Benchmarking Baseline selection.

The proposed hybrid metaheuristic framework will be contrasted with three different categories of algorithms in order to provide a fair and in-depth assessment:

Classical Deterministic Approaches: Standard Frontier-Based Exploration will be used as the main baseline used to evaluate the efficiency of baseline exploration. This will underscore the weakness of deterministic approaches in the dynamic environment.

- Centralized Coordination Strategies: The comparative baseline on the task allocation methods to be applied in the marketplace and auction will be used to measure the computational overhead and communication overhead. The comparison to be made in this context will be the benefits of the proposed decentralized metaheuristic solution in minimizing communication bottlenecks.
- General Metaheuristic Algorithms: To isolate and demonstrate the merits of the intelligent hybrid essence of the suggested framework, it will be analyzed in relation to the unaltered versions of Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) used as the standard ones.

8.2 Experimental Design of Test and Scenarios

The comparative analysis will not be pinned down to one ideal situation. Instead, it will be exposed to a matrix of complicated test scenarios modelled in ROS and Gazebo to test the algorithms under the conditions of the real world:

- Scalability Testing (Swarm Size Variation): Scalable algorithms will be tested with different swarm sizes (e.g. N = 5, 10, 20, 50 robots). This will confirm whether the proposed framework has a sub-exponential growth in computational complexity over the traditional centralized techniques.

Environmental Dynamism (Obstacle Density and Movement): The structures will be tested in conditions of different densities of immobile objects (static obstacles) and moving objects (dynamic obstacle introduced). This will involve the real time path replanning and collision

avoidance of the metaheuristic approach against the traditional planners.

- Communication Degradation Scenarios: Artificial communication constraints will be used in order to mimic real-world physical constraints. The suggested framework will be contrasted with the baselines in the circumstances of intermittent connectivity, limited communication ranges, and simulated packet loss to demonstrate that it is more resilient.

9. Expected Outcomes of the Research

The desired findings of the proposed study are:

1. Construction of a new intelligent metaheuristic model of multi-robot coordination.
2. Better exploration in dynamic and changing systems.
3. Minimization of unnecessary exploration and task conflicts among robots.
4. Improved large team multi-robot scalability.
5. Funding towards the development of autonomous robotic exploration systems.

It is expected that the successful completion of this doctoral research will result in major contributions to the theoretical, algorithmic as well as practical contributions to the area of autonomous multi-robot systems. The anticipated results of this proposed study are multi-dimensional and contain the following main deliverables by addressing the intrinsic constraints of deterministic and centralized control approaches:

9.1 Novel, Adaptive Metaheuristic Architecture This will result in the first, most concrete deliverable, which is the design, development and validation of a new intelligent metaheuristic architecture explicitly designed to address multi-robot coordination. As opposed to the traditional non-adaptive algorithms, such a framework will be inherently able to adjust its optimization parameters in real-time. Incorporating into the design a hybrid algorithm like the Particle Swarm Optimization (PSO) and the Genetic Algorithms (GA) will offer the resulting architecture a strong mathematical basis of decentralized decision-making within robotic swarms in environments where significant levels of uncertainty exist.

9.2 Documented Advances in Exploration and Energy Saving A potential milestone of significant interest is that dramatically more efficient exploration systems will be demonstrated when put to work in dynamic and truly evolving systems. The study will statistically

demonstrate a statistically significant decrease in the time taken to map the unknown regions with the use of rigorous simulation as opposed to classical frontier based work. Moreover, the framework will result in a radical decrease in unnecessary exploration and overlapping of tasks between robots by actively maximising the allocation of tasks to different robots. This optimization directly corresponds to reduced overall kinetic energy usage and longer operational battery life of the swarm as a whole, an important measure in real life applications in disaster recovery or space exploration.

9.3 Improved Scalability and Fault Tolerance under Resource-Constrained Conditions Although classical algorithms tend to fail as the size of robotic deployments increases, the bottlenecks become computational. This study anticipates providing a higher level of scalability of large multi-robot teams. The metaheuristic framework proposed will be decentralized to ensure that the computational load will be manageable at the level of individual robots and therefore, the swarm size will be able to scale without exponentially increasing the processing time. Moreover, the framework will prove to be highly fault tolerant with coordination and map merging functionality prevailing even in the presence of temporary communication bottlenecks and signal loss.

9.4 Practical contributions to the scientific community and literature other than the algorithmic contributions, this study will have a significant impact on the development of autonomous robotic exploration systems. The very strict comparative analysis and Monte Carlo simulations will produce very credible datasets that will benchmark the performance of metaheuristics with conventional ROS-based navigation stacks. As a result, one of the key anticipated results is a widespread spread of these findings in high-impact journal articles with a Scopus index, which will add to the amount of scholarly information on swarm robotics and dynamic path planning worldwide. Lastly, simulation models created in MATLAB and Gazebo could be used as a reference point to future researchers in Manav Rachna University and other researchers.

References

[1] H. Choset, "Coverage for robotics–a survey of recent results," *Annals of Mathematics and Artificial Intelligence*, vol. 31, no. 1, pp. 113–126, 2001.

[2] B. Yamauchi, "A frontier-based approach for autonomous exploration," in *Proceedings 1997 IEEE International Symposium on Computational Intelligence in Robotics and Automation (CIRA'97)*, 1997, pp. 146–151.

[3] W. Burgard, M. Moors, C. Stachniss, and F. E. Schneider, "Coordinated multi-robot exploration," *IEEE Transactions on Robotics*, vol. 21, no. 3, pp. 376–386, 2005.

[4] R. Simmons et al., "Coordination for multi-robot exploration and mapping," in *Proceedings of the National Conference on Artificial Intelligence (AAAI/IAAI)*, 2000, pp. 852–858.

[5] L. Buonocore, S. R. B. dos Santos, A. A. Neto, and C. L. Nascimento, "FastSLAM filter implementation for indoor autonomous robot," in *2016 IEEE Intelligent Vehicles Symposium (IV)*, 2016, pp. 484–489.

[6] H. F. Cappel, "A hierarchical multi-robot mapping architecture subject to communication constraints," *arXiv preprint arXiv:2102.01641*, 2021.

[7] J. De Hoog, S. Cameron, and A. Visser, "Autonomous multi-robot exploration in communication-limited environments," in *Proceedings of the 11th Conference Towards Autonomous Robotic Systems (TAROS 2010)*, 2010, pp. 68–75.

[8] U. Jain, R. Tiwari, S. Majumdar, and S. Sharma, "Multi robot area exploration using circle partitioning method," *Procedia Engineering*, vol. 41, pp. 383–387, 2012.

[9] M. N. Samson and N. Agmon, "Competitive coverage: (full) information as a game changer," in *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2020, pp. 6633–6640.

[10] N. Hazon and G. A. Kaminka, "Redundancy, efficiency and robustness in multi-robot coverage," in *Proceedings of the 2005 IEEE International Conference on Robotics and Automation (ICRA)*, 2005, pp. 735–741.

[11] M. Pavone, A. Arsie, E. Frazzoli, and F. Bullo, "Distributed algorithms for environment

partitioning in mobile robotic networks," *IEEE Transactions on Automatic Control*, vol. 56, no. 8, pp. 1834–1848, 2011.

[12] U. Jain et al., "Robot dispersion using partitioning," *Procedia Engineering*, 2012.

[13] J. Banfi, A. Quattrini Li, I. Rekleitis, F. Amigoni, and N. Basilico, "Strategies for coordinated multirobot exploration with recurrent connectivity constraints," *Autonomous Robots*, vol. 42, no. 4, pp. 875–894, 2018.

[14] J. K. Verma and V. Ranga, "Multi-robot coordination analysis, taxonomy, challenges and future scope," *Journal of Intelligent & Robotic Systems*, vol. 102, no. 1, p. 10, 2021.

[15] H. Chaabi, "Distributed Multi-Robot Exploration With Connectivity Maintenance Under QoS Constraints," Ph.D. dissertation, Université de Lille, 2025.

[16] Y. Emam, S. Mayya, G. Notomista, A. Bohannon, and I. Egerstedt, "Adaptive task allocation for heterogeneous multi-robot teams with evolving and unknown robot capabilities," in *2020 IEEE International Conference on Robotics and Automation (ICRA)*, 2020, pp. 7719–7725.

[17] J. Gielis, A. Shankar, and A. Prorok, "A critical review of communications in multi-robot systems," *Current Robotics Reports*, vol. 3, no. 4, pp. 213–225, 2022.

[18] D. B. Licea, M. Ghogho, and M. Saska, "When robotics meets wireless communications: An introductory tutorial," *Proceedings of the IEEE*, vol. 112, no. 2, pp. 140–177, 2024.

[19] A. Quattrini Li et al., "Multi-robot online sensing strategies for the construction of communication maps," *Autonomous Robots*, vol. 44, no. 3, pp. 299–319, 2020.

[20] M. Saboia et al., "Achord: Communication-aware multi-robot coordination with intermittent connectivity," *IEEE Robotics and Automation Letters*, vol. 7, no. 4, pp. 10184–10191, 2022.

[21] A. Prorok et al., "Beyond robustness: A taxonomy of approaches towards resilient multi-robot systems," *arXiv preprint arXiv:2109.12343*, 2021.

MANAV RACHNA UNIVERSITY

No. MRU/SVLRC/LIB: ....19/03/..2026

Swami Vivekananda Library and Resource Centre
Manav Rachna University

SIMILARITY VERIFICATION CERTIFICATE

Title: An Intelligent Metaheuristic Framework for Multi-Robot Coordination in Evolving Environments

Researcher: Tushar Gupta Registration Number: MRUMEON012K250023

Supervisor: Dr. Priyanka Bansal Department: Mechanical

Co-Supervisor Dr. JP Sharma

This is to certify that the above mentioned Short Synopsis/Thesis was scanned for similarity index through Drill bit Software on 19/03/26.... with submission ID 5367456 and the similarity index was found to be ....3.....%. The complete report running into 16... Pages, 4334....Word count with File Size 1010.....KB, is being forwarded to the Research Supervisor/DRC/DRB for review.

The complete report of the above Short Synopsis/Thesis has been reviewed and the similarity index including AI-based writing tools are below the accepted norms as per the University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018. The Short Synopsis/Thesis may be considered for further processing.

Swami Vivekananda Library and Resource Centre, Faridabad ★ Manav Rachna University ★
19/3/2026

Research Scholar

Priyanka
Research Supervisor

Library

Excluding matches less than 14 words

Excluding matches less than 14 words

19/3/2026

DrillBit

Priyanka

The Report is Generated by DrillBit Plagiarism Detection Software

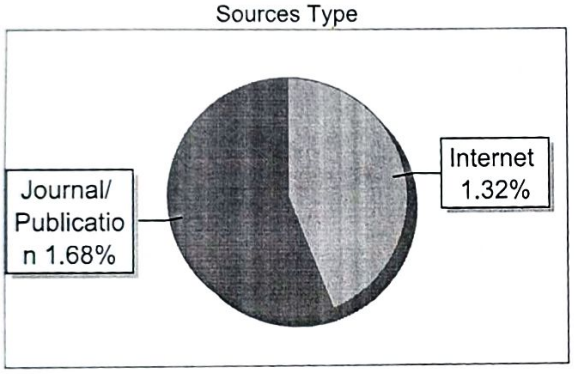
Submission Information

Author Name	Tushar Gupta
Title	Short Synopsis
Paper/Submission ID	5367456
Submitted by	netrapal.library@mru.edu.in
Submission Date	2026-03-19 12:56:18
Total Pages, Total Words	16, 4334
Document type	Synopsis

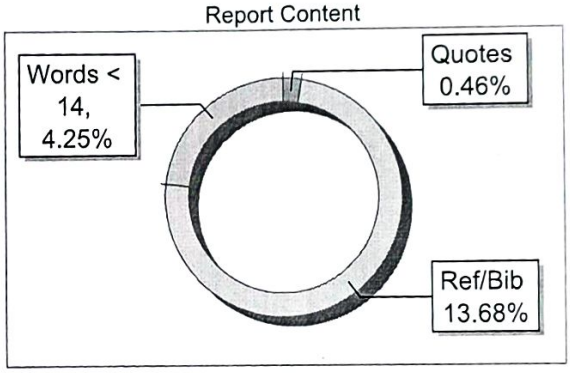
Result Information

Similarity **3 %**

Sources Type



Report Content



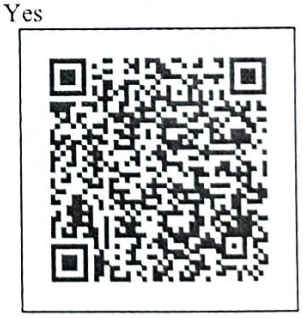
Exclude Information

Quotes	Excluded
References/Bibliography	Excluded
Source: Excluded < 14 Words	Excluded
Excluded Source	**0 %**
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File



Swami Vivekanand... Library and Resource Centre, Gardabad
19/3/2026
Manav Rachna University

Excluding matches
less than 14 words

DrillBit

Priyanka

DrillBit Similarity Report

3	5	A
SIMILARITY %	MATCHED SOURCES	GRADE

A-Satisfactory (0-10%)
B-Upgrade (11-40%)
C-Poor (41-60%)
D-Unacceptable (61-100%)

LOCATION	MATCHED DOMAIN	%	SOURCE TYPE
2	mdpi.com	1	Internet Data
4	www.bil.ac.uk	1	Publication
5	www.mdpi.com	<1	Internet Data
6	Decentralized adaptive awareness coverage control for multi-agent networks by Chen-2011	<1	Publication
7	Sharing across Multiple MapReduce Jobs, by Nykiel, Tomasz Pot- 2014	<1	Publication

An Intelligent Metaheuristic Framework for Multi-Robot Coordination in Evolving Environments

SHORT SYNOPSIS

by

Tushar Gupta
Registration No. MRUMEDN012K250023

Under the supervision of

Dr. Priyanka Bansal
Program Head & Professor

Dr. J P Sharma
Associate Professor

MANAV RACHNA UNIVERSITY

Year *2025-2026*

ABSTRACT

The autonomous multi-robot systems has been adopted as one of the central research topics in the field of robotics in the sense that it is able to perform intricate tasks successfully through the assistance of the cooperative behavior. Most of activities in which robots are currently utilized in the present time including disaster management, environmental inspection, search

DrillBit

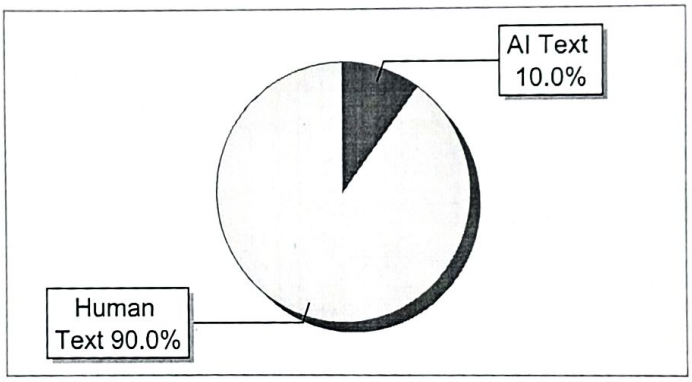
The Report is Generated by DrillBit AI Content Detection Software

Submission Information

Author Name	Tushar Gupta
Title	Short Synopsis
Paper/Submission ID	5367456
Submitted By	netrapal.library@mru.edu.in
Submission Date	2026-03-19 12:56:18
Total [Pages,Sentences,Words]	[16, 178, 3717]
Document type	Synopsis
Language	English

Result Information

AI Text: **10 %**



Disclaimer:

* The content detection system employed here is powered by artificial intelligence (AI) technology.
* Its not always accurate and only help to author identify text that might be prepared by a AI tool.
* It is designed to assist in identifying & moderating content that may violate community guidelines/legal regulations, it may not be perfect.